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April 2, 1993

FCC - MAILROOM

Office of the Secretary
Federal Communications Commission
1919 M Street NW
Washington, DC 20554

Dear Madam Secretary,

Enclosed are my comments of the Notice of Proposed Rule Making, ET Docket No. 92-298. An original and nine copies are enclosed. Thank you.

Respectfully submitted,

David L Hershberger

David L. Hershberger

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Before the

FEDERAL COMMUNICATIONS COMMISSION

CONTENTS

SUMMARY

If anything, the past eleven years' experience firmly established that Motorola AM stereo is a failure. The Commission proposal to adopt the Motorola C-Quam system for AM stereo broadcasting would perpetuate the stagnation, technical failure, business failure, and failure of Motorola AM stereo to serve the public interest. Such a decision would cause permanent harm to the broadcasting business and would preclude the use of better technology.

Linear independent sideband (ISB) would provide greatly superior AM stereo service. It is possible to implement a new AM stereo system using linear ISB without obsoleting any transmitting equipment. Kahn ISB could be used as an interim standard.

Existing AM stereo receivers could still receive linear ISB with a stereophonic effect.

INTRODUCTION

Although the undersigned (David L. Hershberger) is a former employee of the Broadcast Group of Harris Corporation, these Comments are solely those of the undersigned and do not represent Harris Corporation in any way. The undersigned has no financial interest whatsoever in AM stereo; these Comments are intended only to benefit the AM broadcast industry and the consumer.

ANALYSIS

By any measure, the Motorola AM stereo system has been a disaster. It is a business failure, an implementation failure, a technical failure, and hence has failed to serve the public interest. If the past eleven years have proven anything, it is that Motorola AM stereo has utterly failed to serve the public interest. In this "marketplace" there have been no winners. The receiver manufacturers have not won, the broadcasters have not won, none of the system proponents have won, and the public interest has certainly not won.

Now more than ever before, the AM broadcasting industry needs *the best possible technology* to meet the present competition from FM, CDs, tapes, and the near future competition from digital audio broadcasting. Having two loudspeakers which produce the somewhat worse sound quality than conventional AM radio (with some additional distortion, platform motion artifacts, and increased adjacent channel interference) is not the solution.

Motorola AM stereo has not brought about any perceivable business improvement to owners of AM broadcast stations. On the other hand, Rush Limbaugh has single handedly done far more in much less time to revive AM radio than has Motorola AM stereo (perhaps because the Limbaugh program is *monaural*). Motorola AM stereo is a business failure. AM station owners are business persons and if Motorola AM stereo provided any business advantage, it would have been widely implemented.

In spite of a massive decade-long propaganda push by Motorola, apparently including the coercion of receiver manufacturers not to produce multi-system receivers, only about a tenth of all AM broadcasters use the system. AM stereo radios are generally available only in some US made automobiles. Finding an AM stereo radio for sale in a store is an extraordinary occurrence. Motorola AM stereo is an implementation failure.

Something may be learned from Motorola's experience in the foreign countries mentioned in the NPRM. In none of these countries has Motorola AM stereo been a sterling success. Why should it be expected to be any different here?

MOTOROLA'S TECHNICAL FLAWS

Motorola AM stereo is a technical failure for the following reasons:

1. Under adverse propagation or interference conditions, Motorola AM stereo will cause distortion above and beyond the envelope detected monaural signal, lose separation, and/or switch to monaural. All of these effects are noticeable and irritating.

2. Motorola AM stereo occupies excessive bandwidth. This is especially evident since the Commission's adoption of rules requiring (a) pre-emphasis and (b) 10 kHz lowpass filters. In the past, Motorola relied on the gentle rolloff of high frequency audio and audio processing harmonics in the 15-25 kHz range to mask high order sidebands. Now there is an abrupt 10 kHz audio cutoff, which leaves Motorola's high order sidebands "nowhere to hide." Pre-emphasis aggravates the problem. Motorola's high order interference sidebands are plainly and commonly audible now that these rule changes have taken effect. The distortion sidebands can be recognized by any amateur radio operator or radio engineer familiar with the sound of spurious odd-order intermodulation splatter caused by a misadjusted SSB transmitter. Whereas first order high frequency sidebands from a properly operated monaural AM transmitter only have a frequency translation effect, the high order predistortion sidebands emitted by Motorola AM stereo stations have a raspy sound quality with pops and clicks. These predistortion sidebands cause interference to adjacent channels. It is fairly easy to tell if a station is broadcasting Motorola AM stereo using a *monaural* radio. When tuning across the station, if there are ugly sounding (popping, crackling) sideband "tails" 20-30 kHz away, the chances are that the station is broadcasting Motorola AM stereo. Again, this has become a much easier test to perform since the Commission's rules have had the effect of making frequency response and audio bandwidth more consistent from one station to the next.

3. Motorola AM stereo has a built in distortion anomaly under high modulation conditions allowable under the proposed rules. The distortion occurs in stereo receivers when (1) there is any stereo content and (2) L+R modulation approaches or reaches -100% (envelope pinch off). To avoid the pops and clicks which doomed the Magnavox and Belar AM stereo systems, Motorola limits the gain of its so-called "distortion corrector" in its receivers, apparently to a value of about 4 (12 dB). Consider the very frequent occurrence where the left channel is modulated -40% and the right channel is modulated -60%. At this instant, L+R is modulated -100% and L-R is modulated 10%. But since the envelope is pinched off, L-R cannot be recovered. The receiver's L-R detector goes to zero. This causes "nipples" to appear on the detected right channel waveform negative peaks, which now extend to -50% instead of the desired -40%, and "inverted nipples" on left channel modulation peaks, which are compressed to -50% instead of the

2. Occupied bandwidth the same as monaural.

The primary unique merits of the Kahn system are:

1. A high degree of stereo separation is maintained in the presence of selective fading and skywave propagation and co-channel interference.

2. Only an ISB type system such as the Kahn system can be expected to work *in stereo* in a synchronous transmission system, where multiple transmitters carrying the same program from different geographical locations may interfere with one another.

Basically, the Harris system ideally had no distortion under adverse conditions, and the Kahn system ideally had very little loss of stereo separation under adverse conditions.

As a result of extensive field experience with these two AM stereo systems, broadcasters supported one or the other depending on whether they believed that the low distortion of the Harris system or the high stereo separation of the Kahn system was most important.

The remaining systems, (Motorola, Magnavox, and Belar) systems had no outstanding technical merit with the possible exception of low receiver cost. The Magnavox and Belar systems both had a fatal flaw: pops and clicks in stereo under conditions of high L+R modulation. The Motorola system substitutes a kind of distortion for the pops and clicks of Magnavox/Belar systems.

CONTENTIONS MADE IN THE NPRM

The statement in the NPRM, "Broadcasters, manufacturers, and radio purchasers have, directly or indirectly, demonstrated strong preference for the Motorola system." This statement is simply not true.

By no stretch of the imagination can an implementation level of 10% be considered "strong preference."

With the exception of US auto manufacturers, in the early 1980s almost every receiver manufacturer who toyed with AM stereo offered *just one model* with Motorola AM stereo. After a few years of such market testing, most receiver manufacturers dropped this minimal level of support. There is no way this can be imagined to be "strong preference" for Motorola AM stereo.

Purchases of AM stereo radios seem to be largely accidental or incidental. In other words, most AM stereo radios have been purchased because they happened to be part of an automobile purchased for the purposes of transportation. Unlike some purchases of stereo TV sets, there is little or no evidence to support the contention that consumers have shown a "strong preference" for Motorola AM stereo.

The Commission states, "We believe that selection of an alternative to the Motorola system would set back the clock on the implementation of AM stereo service..." The allegorical clock referenced in this statement broke and "stopped ticking" about eight years ago. What we need is a *new* clock that will *work properly.*

THE COMMISSION'S WITHDRAWAL OF THE FAILED CBS COLOR TELEVISION SYSTEM

CBS, proponent of the field-sequential color TV system, no doubt felt the same way when CBS color television was shown to be a failure. The Commission had adopted the CBS color television system, and fortunately, after implementation and technical problems thwarted color television, the Commission withdrew the CBS color television standard to pave the way for a superior system (NTSC). Withdrawal of the CBS color television system did "set back the clock on the mode, the DSP might be used for equivalent IF bandpass filtering, noise reduction by adaptive filtering, and a 90 degree audio phase shift could be easily

1. 90 degree L+R/L-R audio phase difference prior to final audio processing.

2. Transform processing prior to stereo generator.

The 90 degree phase difference introduced between L+R and L-R would convert the quadrature type signal to an ISB type signal.

(A station using the Harris system would only need the 90 degree audio phase shift.)

The transform processing would translate or predistort the left and right channel audio signals such that the Motorola AM stereo generator/transmitter combination would produce a linear signal. With these two operations, the AM stereo broadcaster could transmit a superior linear ISB signal, while still benefiting from the use of existing "C-Quam" equipment.

The Motorola system (or any AM stereo system) exciters can be viewed as signal processors which accept two variables (left and right) and produce an output with two degrees of freedom (envelope amplitude and carrier phase; or alternatively, in-phase and quadrature components). An adaptor box would perform a transformation on the left and right audio signals which produce transformed left and transformed right signals. These transformed audio signals multisystem receivers may recall that regardless of what system an AM stereo station happened to be transmitting, the signal sounded nearly equally "stereo" in both settings of the "A-B" switch. That switch selected or deselected the ISB phase difference networks. Only on sources which were highly localized with little ambience would it become clear which was the "correct" position of the switch.

Basically, the 90 degree phase shift causes highly localized stereo sources to become ambient, and it transforms some ambient sounds (in quadrature between left and right) to become localized.

So, if AM stereo were changed to linear ISB and if the 25 Hz pilot were left unchanged, then users of existing Motorola receivers would still hear a spacious stereo effect on most program material.

The conclusion is that no hardware would necessarily be rendered obsolete. Stations could adapt existing "C-Quam" exciters to produce linear ISB (or through the appropriate transform, virtually any kind of signal). Existing receivers could still be used to receive a spacious and pleasing stereo effect, although highly localized stereo images would be "spread out."

COMPATIBILITY PROCESSING FOR LINEAR ISB

The undersigned has researched various forms of linear ISB AM stereo. Comments of Harris Corporation in Docket 21313 describe some of that linear ISB research. One finding was that the compatibility control system developed by the undersigned while employed by Harris for application to linear quadrature AM stereo is also applicable to linear ISB.

Briefly, the Harris system included an audio processing system which monitored the distortion produced by nonlinear envelope detection, and controlled the maximum negative single channel modulation limits to assure subjective compatibility (the only kind of compatibility which really matters) with envelope detector receivers. This compatibility processing did very little to the signal under most circumstances.

The experience of Harris and many AM stations with the Harris linear AM stereo system has firmly established that linear quadrature AM stereo without this "compatibility processing" is "almost compatible," and that the minimal audio processing of the Harris compatibility controller renders linear quadrature subjectively compatible with envelope detector receivers.

As far as compatibility with envelope detectors goes, the difference between linear quadrature and linear ISB is only statistical.

One observation made during development of the compatibility controller was that unprocessed independent sideband is also "almost compatible," and can also be made compatible with envelope detector receivers through the use of nearly identical compatibility controller processing. ISB and quadrature systems do not exhibit the same level of compatibility. Although envelope detector total harmonic distortion (THD) figures are significantly lower for ISB than for quadrature, the audibility of envelope detector distortion of an ISB signal somewhat worse. Even though the THD is less, there is more envelope distortion at harmonic orders above the second harmonic. There is more distortion at the objectionable higher orders (e. g. sixth, seventh, eighth, etc.). Although the "compatibility controller" must work somewhat harder in an ISB system, the concept has been shown to work.

PILOT TONES and OPTIONS FOR EXISTING RECEIVERS

As for AM stereo pilots, at least two options exist:

1. 15 Hz could be used to indicate linear ISB. In this case, existing Motorola receivers would receive the new ISB signal in monaural.

2. 25 Hz could be used to indicate linear ISB. In this case, existing Motorola receivers would produce a pseudo-stereo effect on linear ISB stations.

Using a 25 Hz pilot, single-system Motorola receivers would receive the linear ISB signal in "pseudo-stereo." This writer has experimented with the subjective effects of reception of ISB signals on quadrature receivers and ISB reception of quadrature signals. Both give the same effect due to a 90 degree "twist" in the L-R signal. Although the measured stereo separation using single channel modulation is an unimpressive zero dB in this case, the subjective effect is stereophonic spaciousness. When a 90 degree phase network is alternately switched in and out, the subjective effect is one where well-defined stereo images (e. g. an image somewhere off to the left) become "smeared" between left and right, but ambience and "width" of the overall stereo effect remain about the same. On the other hand, with a 90 degree phase shift in the matrix, some ambient sounds tend to become localized. This effect was familiar to many users of the Sony SRF-A100 multisystem AM stereo radio when listening to an AM stereo station of an unknown system; sometimes it would take quite a few tries of the "A" (quadrature) - "B" (ISB) switch before it can be decided which position gives best stereo separation.

In other words, even though the Motorola receivers were not designed to receive ISB, there would nevertheless be a stereo effect.

USE OF LINEAR ISB

significant benefit of a linear system which should not be underestimated is synchronous detection in receivers. The primary benefit of synchronous detection is the complete elimination of nighttime envelope detector distortion due to multipath skywave and skywave/groundwave interference. The undersigned has been listening to AM radio on a wideband synchronous detector receiver for over ten years. The undersigned is now "spoiled" and finds nighttime AM reception on envelope detector radios intolerable. It is the opinion of the undersigned that if a small but significant number of synchronous detector radios are made available, then once the general public becomes accustomed to the superiority of synchronous detection, the public at large would also become "spoiled." A good many of the remaining envelope detector radios will be unused for AM reception or returned for warranty "repair." AM improvement, especially for nighttime reception, would be greatly enhanced by synchronous detection.

It should be pointed out that over seven years ago, Sony introduced the ICF-2010 AM/FM/LW/SW radio with synchronous detection. This product has become somewhat of a legend. It is still available and has enjoyed an unusually long product lifetime. Its synchronous detector is particularly well implemented and is well known among radio hobbyists. (Other manufacturers' use of synchronous detection, such as the Drake R-8 receiver, are not nearly as well implemented as the Sony ICF-2010).

SYNCHRONOUS AM: ONLY ISB IS USABLE

One issue which was never addressed in AM stereo Docket 21313 is synchronous transmitters. Synchronous AM transmitters pose a severe problem for non-ISB AM stereo systems in the "overlap" area where the signal strengths from two or more transmitters differ by less than about 20 dB. The stereo image will be upset in this case. When the two transmitters are close in frequency but not phase locked, the stereo image will wander ("platform motion"). Even if the two transmitters are phase locked, automobile reception will result in a wandering stereo image whenever the car is in motion. These effects can be greatly reduced through the use of an ISB type system. Although a nonlinear ISB system (such as the current Kahn system) will exhibit some distortion in the overlap region due to the use of envelope detection, there will be minimal stereo image disruption. A linear ISB system would have no image disruption and no distortion. If the Commission considers synchronous AM transmitters to be a consideration, ISB AM stereo is the *only* system which is usable in stereo in the overlap areas.

MOTOROLA SYSTEM TECHNICAL PROBLEMS

The Motorola system is nonlinear. A characteristic of nonlinear systems is wider occupied bandwidth than linear systems. The Motorola system occupied bandwidth is in violation of 73.128 (b) (1) and 73.128 (b) (1) (iii).

The following characteristics of the Motorola system are questioned:

1. Motorola system occupied bandwidth.

2. Absence of L-R lowpass filtering required by the Commission.

3. The Motorola "distortion corrector" cannot possibly remove predistortion generated at or very near -100% envelope modulation; consequently, the Motorola system is incapable of meeting distortion rules set out in paragraph 73.40 (b) (2) (in force at the time of type acceptance) when L and R are simultaneously modulated such that L+R modulation is very close to -100%.

OCCUPIED BANDWIDTH OF THE MOTOROLA SYSTEM

It has long been known that the Motorola system occupies the widest bandwidth of all of the AM stereo systems currently in use. The Motorola system's high order sidebands, of orders 4, 5, 6, etc., are larger than those of the Kahn, Magnavox, or Harris systems. It is these high order sidebands which cause interference to second and third adjacent channels.

The Motorola system also has high amplitude second and third order sidebands. These sidebands cause interference primarily to first and second adjacent channels.

FCC rule 73.128 (b) (1) plainly states:

> "The transmitted wave must meet the occupied bandwidth specifications of 73.44 under **all possible conditions of program modulation**."

(Emphasis added). Motorola, in its application for type acceptance, only provided stereo occupied bandwidth tests at audio frequencies up to 5000 Hz. Motorola simply ignored the cases where its occupied bandwidth exceeds FCC limits. Since the Commission specifically requires monophonic transmitter type acceptance data at 7.5 kHz (to show whether the transmitter in question violates the -25 dB limitation at 15 kHz), the omission of data above 5 kHz is a glaring "oversight."

"All possible conditions of program modulation" means just what it says - any possible modulation condition. This includes modulation from -100% to +125% modulation or the proponent's stated limits, whichever is less. Since Motorola did not elect to include a 7.5 kHz lowpass filter as required by the Commission, the gamut of valid tests includes tones through at least 15 kHz. Since Motorola does not include modulation limiting equipment, the gamut of valid tests also includes single channel modulation up to and including 100%.

The Motorola system violates 73.44 under the following conditions of modulation:

1. Single channel, single tone modulation at frequencies above 7.5 kHz at

any level at or above 67% modulation.

2. Two-channel, single tone modulation at frequencies above 7.5 kHz such that L+R is modulated 100% and L-R is modulated at least 45%. This can be done by modulating L 72.5% and R 27.5%. If L is increased beyond 72.5% and R decreased below 27.5%, the spectrum will go further beyond legal limits.

3. Single tone simultaneous L+R and L-R modulation, with L+R and L-R audio tones 90 degrees out of phase ("Motorola CSSB") at frequencies above 7.5 kHz at any level above 64% modulation.

4. Two tone modulation, with one tone in L+R at 100% modulation, and another tone modulating L-R at least 57%, such that the sum of the frequencies is greater than 15 kHz. In the computer simulation, L+R was modulated with 11 kHz while L-R was modulated with 5 kHz, producing a 16 kHz out of band spur. The significance of this test is that it shows that **a 5 kHz filter in the L-R channel will not ensure compliance** with FCC occupied bandwidth rules.

5. L-R single tone modulation at any frequency above 7.5 kHz at or above 83% modulation.

The fact that the Motorola system violates the standards set by 73.44 under single channel modulation conditions (case 1 above) is well established. Various filings in Docket 21313 by Pioneer, Magnavox, and Harris show the excessive bandwidth of the Motorola system. The March 13, 1986 Kahn complaint documents these violations.

Several proponents have suggested the use of L-R lowpass filtering to control occupied bandwidth of nonlinear systems. The Kahn system includes a 5 kHz lowpass filter in the L-R channel, to eliminate stereo separation above 5 kHz. Magnavox suggested in its Docket 21313 comments a similar lowpass filter for L-R. Motorola has also discussed in its Docket 21313 filings the use of lowpass filtering for bandwidth control.

The Commission stated in the **Report and Order** adopted March 4, 1982 that the L-R (stereo) frequency response of the Motorola system must be limited to 7.5 kHz:

"**Spectral distribution of emissions**

"When operating in the stereo mode, the Magnavox, **Motorola**, Belar and Kahn/Hazeltine systems generate both intermodulation products and higher order sidebands of the modulating frequencies. To prevent excessive distortion of the signal, at least the second order sidebands produced by the modulating frequencies must be retained. To do this and still stay within the Commission's rules, Magnavox, **Motorola**, and Belar **limit the frequency response of their separation information to 7,500 Hz**. The Kahn/Hazeltine system limits separation frequencies to 5,000 Hz. However, a linear system can attain stereo separation up to 15,000 Hz."

(**Report and Order**, page E3, emphasis added.)

The Commission reiterates the bandwidth restriction on Motorola:

"By contrast, the stereophonic (L-R) channel full modulation frequency response for the Magnavox, **Motorola**, and Belar systems is 50-7500 Hz and for the Kahn/Hazeltine system only 50-5000 Hz. These frequency limitations are inherent features of these systems and cannot be improved **within the existing bandwidth restriction**."

(**Report and Order**, page E4, emphasis added.)

Inspection of the Motorola application for type acceptance reveals that the lowpass filtering of the L-R signal, required by the Commission, is not present.

Motorola, in its application for type acceptance, did not make stereo occupied bandwidth measurements at any frequency higher than 5 kHz. By not making such tests, the effectiveness of a 7.5 kHz L-R lowpass filter cannot be determined. Moreover, by not testing at frequencies higher than 5 kHz, it is not possible to determine if such a filter is even present.

If an ideal 7.5 kHz lowpass filter were enough to guarantee compliance with paragraph 73.44, a real-world filter would have to be somewhat narrower. 7.5 kHz is the beginning of the stopband, which means that in a real-world filter, the passband would have to be somewhat lower. Kahn, for instance, has used a filter with a passband of 5 kHz, which provides high attenuation at 7.5 kHz and above. More recently, Kahn has included a 7.5 kHz lowpass filter in his newer AM stereo exciter.

A 5 kHz lowpass filter in L-R will not guarantee compliance with 73.44 for the Motorola system. Case (4) above will still be violated if, for instance, a 12 kHz tone modulates L+R at 100% and a 4 kHz tone modulates L-R at 60%. The sum of the two frequencies will create an out-of-band component at 16 kHz away from the carrier which exceeds the -25 dB limit. Filters in both L+R and L-R would be required to guarantee compliance. The sum of the stopband cutoff frequencies would have to be less than 15 kHz. For instance, compliance with 73.44 might possibly be achieved with a L-R filter which passes 5 and rejects 6 kHz and a L+R filter which passes 8 and rejects 9 kHz.

During normal programming it is possible for modulation conditions to occur which would violate 73.44. Any of the above cases may occur, causing the Motorola system bandwidth to exceed FCC limits; or other modulation conditions not mentioned above may cause the Motorola system to generate an illegal spectrum.

SPECTRAL CHARACTERISTICS OF THE MOTOROLA SYSTEM UNDER PROGRAM CONDITIONS

I. Measurement methods

Spectral characteristics of broadcast signals are generally objectively measured by applying sinusoidal tones to a system and by observing the output on a spectrum analyzer. Motorola has downplayed the wideband spectral characteristics of its system and has instead suggested "measurement" techniques using program material which are unconventional, contrived, and invalid. Except for some statements made in its patent applications, Motorola has persisted in making invalid "measurements" accompanied by a good measure of hand-waving.

It is common knowledge that if high frequency tones are applied to a nonlinear system such as the Motorola system, that out-of-band emissions can be generated which exceed FCC rules. Motorola has observed, however, that if program material is applied to its system, at any given point, a spectrum analyzer shows that the Motorola system spectrum is apparently much worse with tones than with program material.

To understand why spectrum analyzer "measurement" using program material is an invalid technique, it is necessary to review some very basic fundamentals of Fourier analysis.

II. Fourier Analysis and Spectrum Definition

This may sound like an pedantic and academic argument. But does this line of reasoning have any relevance to the real world? Indeed it does. The spectrum analyzer is a time-averaging device. It averages over a time inversely proportional to its bandwidth (longer if a post-detection "video filter" is used). If a steady-state signal consisting of one or more sinusoidal tones is applied to a system, the spectrum analyzer will yield correct results only as long as its resolution is sufficient to distinguish between any two adjacent spectral lines.

Another way of gaining an intuitive understanding of the inconsistency is to consider that the spectrum analyzer is a sweeping filter. It takes a certain amount of time for the swept filter to move through the signal and measure each component. Actually, the spectrum analyzer is a sample-data system which operates in the frequency domain. Results will be accurate only if "aliasing" is avoided. Intuitively, we would like for the signal to "stand still" as the swept filter moves through the spectrum, recording its shape. In other words, the signal cannot change during the spectrum analyzer sweep time or filter averaging time. This means that the signal being analyzed must be periodic over a sufficiently short interval. Otherwise, there may be inaccuracies due to "aliasing."

But if the spectrum analyzer does not have sufficient resolution, it will lump together various components and time-average them. Moreover, as the spectrum analyzer "sweeps through" the signal, it may miss certain spectral components altogether. (A spectrum analyzer has a very low "probability of interception.")

The interference characteristic of the Motorola system with typical program material is one which generates clicks and pops in adjacent channels. These out-of-band signals, while having a low time-averaged energy content, have considerable power for a short time. In spite of what may be low **long-term** "average" power in Motorola spurious emissions, the **short-term** average may be much higher during a pop or click induced in an adjacent channel. In any event, the interference caused by the Motorola system can be quite annoying.

MOTOROLA'S EISEGETICAL APPROACH TO FCC SPECTRUM RULES

Motorola's attempted justification for its excessive bandwidth depends on a misinterpretation of Commission rules in force at the time of the 1982 **Report and Order** in docket 21313. Motorola would like to believe that its system meets occupied bandwidth during program conditions because each individual spectral line (the existence of which may be undefined due to lack of periodicity) is less than -25 dB with respect to the carrier, even though the total out-of-band energy (the root sum square of the spectral lines) may exceed the Commission's -25 dB limit.

The Commission's rules on occupied bandwidth state that emissions more than 15 kHz away from the carrier must be at least 25 dB down from the unmodulated carrier amplitude. There are some who would like to take this general statement and misinterpret it in a more liberal fashion. They would like to say that the

Commission's rule means, "a signal may have an **unlimited** amount of out-of-band energy, just as long as no **single** spectral line exceeds -25 dB." This misinterpretation of the Commission's rules is ludicrous.

Consider, for example, the case where a 1 kilowatt transmitter is operating, generating various desired in-band signal components and some undesired out-of-band signal components. Let the transmitter input signal be a program segment which is 10 milliseconds long, repeated every 10 milliseconds. Such a condition would satisfy both conditions for evaluation of the Fourier integral; namely, the signal would be both bounded and periodic.

In this case, the transmitter would have sidebands spaced every 100 Hz. Now consider that the transmitter is emitting a set of out-of-band sidebands which extend from 20 kHz away from the carrier to 120 kHz away from the carrier, with each sideband being down 30 dB from the carrier, with such a sideband present every 100 Hz. We now have 1000 out-of-band upper sidebands of 1 watt each, and 1000 out-of-band lower sidebands of 1 watt each. The root sum square of the out-of-band components (e. g., the sum of the powers) yields 2000 watts of out-of-band power. If the -25 dB rule is misinterpreted so as to apply only to each individual sideband rather than to the total of the out-of-band components, then there would be **no limit** to interference power. In our example, we could "legally" have 2000 watts of interference coming out of a 1000 watt (carrier power) transmitter. Even so, the spectrum as viewed on a spectrum analyzer would appear to be relatively innocuous by Motorola's standards, since the offending energy would be "spread out" rather than appearing in a single spectral line.

On page 167 of the February 9, 1981 Docket 21313, **Comments of Harris**

If we want to measure out-of-band emissions with program material, then a spectrum analyzer is inappropriate because (1) the signal is not periodic, (2) a spectrum analyzer has insufficient resolution, and (3) the spectrum analyzer is a time-averaging device. Actually, it would seem that a spectrum analyzer, which is a sweeping filter, is rather a roundabout method of trying to measure what we really want. Why not directly measure what we want, with a fixed filter instead of a sweeping filter?

For example, say that we have a signal with a carrier frequency of 1 MHz to check for out-of-band emissions according to FCC rules. To accomplish this, we would like to have a filter which would block out all of the permissible sidebands, and pass the undesired ones for measurement. This is exactly what an audio distortion analyzer does. An ideal rectangular bandstop filter which would reject everything from 985 kHz to 1015 kHz but pass everything else, would do the job.

respond to **total** energy in the wide bandwidth, and will not make the out-of-band emissions appear artificially low by time-averaging and by displaying only one narrow segment of the out-of-band emissions at any given time. A radio will preserve the characteristic "click" and "pop" sounds of out-of-band spurious emissions. Although the average out-of-band energy may sometimes be low, the clicks and pops can be highly annoying.

The proposed measurement method is highly representative of what real radios will do in the presence of adjacent channel interference from a Motorola station.

One situation familiar to radio engineers is where an off-tuned radio, as described above, detects "splatter" sidebands from an overmodulated conventional AM (mono) transmitter. FCC 73.55 prohibits negative overmodulation of peaks of frequent recurrence. One reason overmodulation is undesirable is that the occupied bandwidth increases. Listeners to adjacent channels hear annoying clicks, pops, and sputtering noises caused by overmodulation. The Commission's prohibition of frequent overmodulation is well-reasoned, since it is well known that overmodulation produces an objectionable increase in occupied bandwidth, and causes interference to adjacent channels.

Motorola has argued that the high-order sidebands produced by its system are not harmful, claiming that most are in-band, the out-of-band sidebands are of low amplitude, modulation is "low" at higher modulating frequencies, and that the predistortion sidebands are "masked" by transmitter distortion. (The last two arguments are no longer valid in light of the 10 kHz lowpass filter & pre-emphasis rules.) Many of these claims are simply not true. Regardless of the validity of these arguments, they may also be applied to try to justify the use of overmodulation. It may be argued that the high-order sidebands caused by overmodulation are also mainly in-band, low in amplitude, etc. However, any radio station consistently overmodulating its transmitter would be and should be cited if monitored by FCC engineers. Stations with out-of-band emissions should be cited regardless of their cause, whether they be due to simple overmodulation or due to an AM stereo system which inherently exceeds established Commission rules.

Harris submitted data to the Commission on August 3, 1979 in connection with Docket 21313, which showed that the interference and bandwidth increase of a nonlinear AM stereo system such as Motorola is comparable to the interference and bandwidth increase which is caused by consistently overmodulating a monophonic transmitter by 30%. [**Reply Comments of Harris Corporation on Notice of Proposed Rulemaking**, Appendix XI, August 3, 1979.]

MOTOROLA MISREPRESENTATIONS REGARDING ITS SPECTRAL CHARACTERISTICS

Motorola has made statements to the Commission which are contradicted by Motorola statements made to the U. S. patent office. In **Reply of Harris Corporation to the Late-Filed Comments of Motorola Corporation, Kahn**

Communications, Inc. and Hazeltine Corporation; January 10, 1980, statements made by Motorola to the Commission were compared with contradictory statements made to the Patent Office. For instance, Motorola made statements to the Commission extolling the alleged virtues of its system, and made claims that the noise performance of its system was unaffected by the operation of the Motorola "distortion corrector," a variable gain device in the L-R channel. At the same time, Motorola acknowledged the noise penalty imposed by the "distortion corrector," and applied for and was granted U. S. patents #4,169,968, #4,159,396, and #4,170,716, all for the purpose of reducing the noise penalty of the Motorola system.

A similar situation exists with regard to the bandwidth of the Motorola system While Motorola has consistently alleged in its statements both to the Commission and to the industry that its system does not have a bandwidth problem, Motorola has made statements to the contrary to the Patent Office in the course of applying for a patent on a scheme to try to reduce the excessive bandwidth of its system. Motorola has been granted U. S. patent # 4,338,491.

In this patent, the entire "Background of the Invention" section is given here:

> "This invention relates to the field of amplitude modulated stereo broadcasting and, more particularly, to a signal having reduced possibility of adjacent channel interference.
>
> "Numerous systems have been devised for AM stereo broadcasting, but all compatible systems represent a compromise with respect to the noncompatible, pure quadrature system. When all or part of that compromise consists of adding some adjacent channel interference, modification of the system may be advisable if the tradeoff does not introduce other and even less desirable characteristics. The most desirable of such trade-offs would be losing a slight amount of stereo separation at the high frequencies only, in return for preventing possible adjacent channel interference."

As the purpose of its scheme, Motorola states:

> "It is an object, therefore, of the present invention to provide a compatible AM stereophonic broadcasting system which will prevent significant adjacent channel interference with no increase in distortion or loss of s/n ratio."

Motorola recognizes that by predistorting the envelope of a pure linear quadrature type signal, the "**compromise consists of adding some adjacent channel interference.**" Motorola proposes greatly reducing high frequency stereo separation in an attempt to reduce adjacent channel interference.

Motorola understates the stereo loss, calling the reduction "losing a slight amount of stereo separation." Upon investigation of the parameters proposed by Motorola, one finds that the high frequency part of the L-R channel is reduced by up to 12 dB. This results in stereo separation of only 4.5 dB, hardly a "slight" loss.

What is interesting is that Motorola is proposing a variable-angle quadrature system for frequencies above 3 kHz! The limits of the Motorola variable-angle system are 28 degrees (12 dB loss in L-R) and 90 degrees (no L-R reduction). Unfortunately, the Motorola high frequency variable angle system is not decodable - it is not possible to undo the L-R separation loss. Consequently, high frequency stereo components would wander around with the Motorola high frequency variable angle system, producing a confused stereo image.

Motorola describes the operation of its high frequency variable-angle system as follows:

> "However, in the event that there is a high level, high frequency signal in one of the L and R channels, there would be sidebands beyond 15 kHz at the output of the encoder 44. These sidebands, which might cause adjacent channel interference, are filtered out in the RF filter 56. In this case, the output signal of the decoder 72 would be an L-R signal distorted in proportion to the high level, high frequencies in the L-R output of the matrix 27. The output signal of the divider 66, representing percent distortion would be averaged and compared with the reference and, if greater than the reference level, the gain of the amplifier 80 would be driven down until the percent distortion signal is no greater than the reference signal level."

Motorola therefore acknowledges its spectral problem to the Patent Office but not to the Commission.

STEREO DISTORTION IN THE MOTOROLA SYSTEM

The Motorola system attempts to simultaneously achieve compatibility and stereo operation by instantaneously companding or predistorting the transmitted envelope. Motorola multiplies the transmitted quadrature envelope by:

(1+L+R) / ((1+L+R)^2 + (L-R)^2)^(0.5))

where ^ denotes exponentiation. Notice that this companding or predistortion function is always equal to or less than one. In the receiver, which must undo the transmitted predistortion, a gain factor is applied to the signal which is the reciprocal of the predistortion function. This is the function of the "distortion corrector." The "distortion corrector" gain is always greater than or equal to one. So, the envelope is compressed at the transmitter and expanded at the receiver.

Consider the case where L=-0.7 and R=-0.3, which corresponds to the negative modulation peak in the situation where L modulation is 70% and R

L and R signals without distortion. Under this modulation condition, it is impossible to recover left and right channels without distortion. Using a "distortion corrector" gain of 4, demodulated left channel distortion will be 9.3% and right channel distortion will be 18.2%.

Since Motorola has informally proposed limiting the gain of the "distortion corrector" to about 4.0 under ideal conditions, and less under nonoptimal conditions, the receiver outputs (both L and R channels) will be distorted. The question is how much distortion is present?

Computer modeling of the Motorola system has been performed to determine the amount of distortion generated when both L and R are modulated such that the sum channel (L+R or envelope) is modulated 100%, and the difference channel (L-R) is modulated something less than that, with a "distortion corrector" gain limit of 4. (It should be noted that this modulation condition occurs perhaps several thousand times per hour in normal broadcast operation).

The distortion levels in the Motorola system under these conditions are:

L+R mod.	L-R mod.	L mod.	R mod.	L distortion	R distortion
100%	100%	100%	0%	18.8%	23.7%*
100%	90%	95%	5%	17.6%	67.6%
100%	80%	90%	10%	16.2%	55.9%
100%	75%	87.5%	12.5%	15.5%	50.2%
100%	70%	85%	15%	14.7%	44.7%
100%	60%	80%	20%	13.1%	34.5%
100%	50%	75%	25%	11.3%	25.7%
100%	40%	70%	30%	9.3%	18.2%
100%	25%	62.5%	37.5%	6.0%	9.2%

* **denotes distortion in R due to L.** When R is not modulated (first row of figures above) the distortion is calculated as:

(rss distortion in R, excluding linear crosstalk term)/(L rss signal)